

CLAIMS:

1. A thermoelectric device comprising:
at least one unipolar couple element having two legs of a same electrical conductivity type;
a first-temperature stage connected to one of said two legs;
a second-temperature stage connected across said legs of the at least one unipolar couple element; and
a third-temperature stage connected to the other of said two legs.
2. The device of Claim 1, wherein said at least one unipolar couple element is configured such that currents flow in opposite directions in the two legs of the at least one unipolar couple element to establish a temperature differential across each of the two legs of said unipolar couple element.
3. The device of Claim 1, wherein said at least one unipolar couple element is configured to generate at least one of an electrical potential and an electrical current from a temperature differential established across the two legs of said unipolar couple element.
4. The device of Claim 1, wherein the at least one unipolar couple element comprises:
a pair of p-type $\text{Bi}_2\text{Te}_3/\text{Sb}_2\text{Te}_3$ superlattice thermoelements.
5. The device of Claim 4, wherein the p-type $\text{Bi}_2\text{Te}_3/\text{Sb}_2\text{Te}_3$ superlattice thermoelements have a ZT of >1 at 300K.
6. The device of Claim 1, wherein the at least one unipolar couple element comprises:
a pair of n-type $\text{Bi}_2\text{Te}_3/\text{Bi}_2\text{Te}_{3-x}\text{Se}_x$ superlattice thermoelements.
7. The device of Claim 8, wherein the n-type $\text{Bi}_2\text{Te}_3/\text{Bi}_2\text{Te}_{3-x}\text{Se}_x$ superlattice thermoelements have a ZT >1 at 300K.
8. The device of Claim 1, wherein the at least one unipolar couple element comprises:
a pair of n-type $\text{PbTeSe}/\text{PbTe}$ superlattice thermoelements.

9. The device of Claim 8, wherein the n-type PbTeSe/PbTe elements comprise:
a pair of n-type PbTeSe/PbTe quantum-dot superlattice thermoelements having a ZT of ~1.6 at 300K.
10. The device of Claim 1, wherein the at least one unipolar couple element comprises:
a pair of p-type PbTeSe/PbTe superlattice thermoelements.
11. The device of Claim 1, wherein the at least one unipolar couple element comprises:
at least one set of p-p and one set of n-n unipolar couple elements.
12. The device of Claim 1, wherein the at least one unipolar couple element comprises:
one set of p-p couples and two independent legs of n.
13. The device of Claim 1, wherein the at least one unipolar couple element comprises:
one set of n-n couples and two independent legs of p.
14. The device of Claim 1, wherein the unipolar couple elements comprise a p-p bulk couple.
15. The device of Claim 1, wherein the unipolar couple elements comprise a n-n bulk couple.
16. The device of Claim 1, wherein the unipolar couple elements are configured to produce temperature differentials in a range from 1K to 200K.
17. The device of Claim 1, further comprising:
a thermal insulation between said first-temperature stage and said third-temperature stage.

18. The device of Claim 17, wherein the thermal insulation comprises at least one of aerogels and polymer sheets.

19. The device of Claim 1, further comprising:

a controller configured to control a temperature of the second-temperature stage to produce desired source and drain temperatures on the first-temperature stage and the third-temperature stage, respectively.

20. The device of Claim 19, wherein said controller is configured to control said current flow to produce said desired source and drain temperatures.

21. The device of Claim 1, wherein said temperature differential across each leg of said two legs is about half a temperature differential between the first-temperature stage and the second-temperature stage.

22. The device of Claim 1, wherein at least one of the first-temperature stage and the second-temperature stage comprises a split header.

23. The device of Claim 1, wherein said third-temperature stage is configured to operate at a temperature about 100 °C so that a phase change of water to steam provides heat removal and said first-temperature stage is configured to operate at a temperature below 40 °C.

24. The device of Claim 1, wherein said third-temperature stage is configured to operate at a temperature about 100 °C so that a phase change of water to steam provides heat removal and said first-temperature stage is configured to operate at a temperature below 10 °C or below.

25. The device of Claim 1, further comprising:

a water-based closed cycle heat removal system connected to the third-temperature stage.

26. The device of Claim 1, wherein the at least one unipolar couple element

comprises:

a p-p couple with each leg of said two legs having at least one of a different material composition and a different structure from the other leg.

27. The device of Claim 26, wherein the p-p couple comprises:

a p-type $\text{Bi}_{1.0}\text{Sb}_{1.0}\text{Te}_3$ thermoelement; and

a p-type $\text{Bi}_{0.5}\text{Sb}_{1.5}\text{Te}_3$ thermoelement.

28. The device of Claim 26, wherein the p-p couple comprises:

a p-type 10 Angstrom/30 Angstrom $\text{Bi}_2\text{Te}_3/\text{Sb}_2\text{Te}_3$ superlattice thermoelement; and

a p-type 10 Angstrom/50 Angstrom $\text{Bi}_2\text{Te}_3/\text{Sb}_2\text{Te}_3$ superlattice thermoelement.

29. The device of Claim 1, wherein the at least one unipolar couple element comprises:

a n-n couple with each leg of said two legs having at least one of a different material composition and a different structure from the other leg.

30. The device of Claim 29, wherein the n-n couple comprises:

an n-type $\text{Bi}_2\text{Te}_{2.5}\text{Se}_{0.5}$ thermoelement; and

an n-type $\text{Bi}_2\text{Te}_{2.85}\text{Se}_{0.15}$ thermoelement.

31. The device of Claim 29, wherein the n-n couple comprises:

an n-type 10 Angstrom/30 Angstrom $\text{Bi}_2\text{Te}_3/\text{Bi}_2\text{Te}_{2.85}\text{Se}_{0.15}$ superlattice thermoelement; and

an n-type 10 Angstrom/50 Angstrom $\text{Bi}_2\text{Te}_3/\text{Bi}_2\text{Te}_{2.85}\text{Se}_{0.15}$ superlattice thermoelement.

32. A thermoelectric device comprising:

at least one unipolar couple element having two legs of a same conductivity type;

an intermediate-temperature stage connected between said legs of the at least one unipolar couple element; and

electrical contacts to each leg of the unipolar couple element.

33. The device of Claim 32, wherein said at least one unipolar couple element is configured such that current flows in opposite directions in the legs of the at least one unipolar couple element to establish a temperature differential across the two legs of said unipolar couple element.

34. The device of Claim 32, wherein said at least one unipolar couple element is configured to generate at least one of an electrical potential and an electrical current from a temperature differential established across the two legs of said unipolar couple element.

35. The device of Claim 32, wherein the at least one unipolar couple element comprises:

a p-p couple with each leg of said two legs having at least one of a different material composition and a different structure from the other leg.

36. The device of Claim 32, wherein the at least one unipolar couple element comprises:

a n-n couple with each leg of said two legs having at least one of a different material composition and a different structure from the other leg.

37. A thermoelectric device comprising:

at least a four-temperature-terminal device including,

a p-p unipolar couple element having legs of a p-type electrical conductivity,

a first intermediate temperature stage connected across said legs of the p-p unipolar couple element,

a n-n unipolar couple element having legs of an n-type electrical conductivity, and

a second intermediate temperature stage connected across said legs of the n-n unipolar couple element and operated at a temperature different than first intermediate temperature stage.

38. The device of Claim 37, further comprising:

electrical contacts connecting to each of said legs of the p-p and said legs of the n-n unipolar couple elements, said electrical contacts are connected such that currents flow in opposite directions in each of the legs of the p-p unipolar couple element and in each of the

legs of the n-n unipolar couple element to establish a temperature differential across each of the p-p unipolar couple element and the n-n unipolar couple element.

39. The device of Claim 37, wherein said p-p unipolar couple element and said n-n unipolar couple element are configured to generate at least one of an electrical potential and an electrical current from a temperature differential established across said p-p unipolar couple element and said n-n unipolar couple element.

40. A thermoelectric device comprising:

a heat source;

means for generating currents flowing in opposite directions in two legs of a thermoelectric material of a same conductivity type, said means coupled to said heat source; and

a heat sink coupled to said two legs and configured to dispose heat from said thermoelectric device.

41. The device of Claim 40, further comprising:

an intermediate-temperature stage connected across said two legs; and

a temperature controller configured to control a temperature of the intermediate-temperature stage.

42. The device of Claim 40, wherein said means for generating currents comprise:

- a metal contact interposed between and connecting to said two legs;
- two electrical contacts connected to respective ends of said two legs opposite said metal contact; and
- a voltage applicator configured to apply an opposite voltage potential to respective of said electrical contacts.

43. The device of Claim 40, wherein said means for generating currents are configured to provide said currents to establish a temperature differential across the two legs.

44. The device of Claim 40, wherein said means for generating currents are configured to generate, from a temperature differential across said two legs, at least one of an electrical potential and an electrical current.

45. The device of Claim 40, wherein said means for generating currents comprise:
a p-p couple with each leg of said two legs having at least one of a different material composition and a different structure from the other leg.

46. The device of Claim 40, wherein said means for generating currents comprise:
a n-n couple with each leg of said two legs having at least one of a different material composition and a different structure from the other leg.

47. A method for cooling an object, comprising:
conducting heat from the object to a thermoelectric device including a unipolar couple element having two legs of a thermoelectric material of a same conductivity type; and
flowing currents in opposite directions in said two legs to transport said heat across each of said legs in a direction away from said object; and
disposing of said heat from the thermoelectric device through a heat sink into an ambient environment.

48. The method of Claim 47, further comprising:
controlling a temperature of an intermediate-temperature stage connected between said legs.

49. The method of Claim 47, wherein said flowing currents comprises:
applying opposite voltage potentials to respective of two electrical contacts at ends of said two legs.

50. The method of Claim 47, wherein said flowing currents establishes a temperature differential across the two legs to cool said object.

51. A method for thermoelectric power conversion, comprising:

extracting heat from a heat source coupled to a thermoelectric device including a unipolar couple element having two legs of a thermoelectric material of a same conductivity type; and

maintaining a temperature differential across the thermoelectric device to a heat sink to produce electrical power from the thermoelectric device; and

dissipating heat from said heat sink into an ambient environment.

52. The method of Claim 51, further comprising:

controlling a temperature of an intermediate-temperature stage connected between said legs to produce electrical power.

53. The method of Claim 51, further comprising

controlling a temperature of an intermediate stage by introducing a fluid exiting from a hot-stage coupled to the heat source onto the intermediate stage.

54. The method of Claim 53, wherein said controlling a temperature mixes said fluid exiting from a hot-stage with a lower-temperature fluid.

55. The method of Claim 51, wherein said maintaining a temperature differential generates at least one of an electrical potential and an electrical current from the thermoelectric device.